# CHAPTER 7
# EARTH-FILL WHARF STRUCTURES

## GENERAL

a. Types of structures. Earth-fill wharf structures differ greatly in size. They may be small, backfilled bulkheads used at the shore ends or the approaches of pile wharves, or they may be large, square-type filled quays. All wharf structures require some type of bulkhead or retaining wall to hold the fall. A quay also needs a vertical face with adequate water depth alongside.

b. Types of bulkheads or quay walls.

(1) Bulkheads for the shore ends of pile wharves or their approaches use planks supported by round piles or braced by batter piles. They need not be higher than approximately 5 feet above high water. Excessive pressure problems are unusual here.

(2) Quay walls for deep-draft ships may involve a fill of 50 feet plus the tide range. Such a structure may feel great earth pressure. It requires careful investigation and design.

(3) Structures for intermediate depths include wharves for ]ighterage and those along the edge of a tidal flat. These efficient structures are easy to construct. Typical examples are described in this manual. They include masonry walls, sheet pile bulkheads, and expedient structures such as rock-fill timber cribs, rock-fill barges, or sunken and anchored pontoon structures.

c. Advantages. Earth-fill structures can be constructed quickly. A permanent structure has a load-carrying capacity equal to that of a road or airfield.

d. Disadvantages. Earth-fill structures must be kept within the bulkhead limit. They also affect the tidal prism and require careful bottom investigation and structural design.

## MOLES AND BREAKWATERS

a. Moles. A masonry mole may be widened by anchoring a bulkhead to it at some distance from its protected face. Engineers can fill and surface the space between the mole and bulkhead.

b. Breakwaters. Engineers may widen a rock-mound breakwater to use. as a wharf. First, they install a bulkhead inshore from the protected face. Then they fill the spaces between breakwater and bulkhead, and between the surfacing material and fill at the top of the breakwater.

## MASONRY QUAY WALLS

Masonry quay walls are usually designed as massive gravity-type retaining walls. But the construction time, preparation, and materials normally preclude new masonry in the TO. Engineers repair existing quay walls with reinforced concrete, masonry, or concrete and masonry combined with an epoxy resin mixture. Expedient methods such as sandbags or timber construction serve for temporary construction. The fill and surfacing of the quay is then replaced.

## SHEET PILE BULKHEAD

a. Materials. Treated timber may be used when useful life expectancy is low. But wood piles are unsatisfactory below the permanent wet line or where marine borers are active. Wood sheet piles are satisfactory only for shallow depths. When steel is justified, it is protected above a level of about 3 feet below mean low water with bituminous coatings on concrete jackets. The tight joints between steel sheet piles make them the most widely-used type of sheet pile. This fact will remain true in TO construction. Figure 7-1 shows a bulkhead constructed with steel sheet piles and steel tie-rods. Concrete may play a role in future pile construction.

b. Earth pressures. A problem in building sheet pile bulkhead quays is the pressure created by the fill on the bulkhead. Earth pressures vary due to the physical properties of soils. Engineers must make thorough surveys and soil examinations of proposed sites. They must establish accurate bottom and onshore contours and study the geology of the area. They must sample soil layers from the surface to underlying rock or to depths where conditions could not affect the structure. They must consider cohesive soils such as clays and silts as bottom materials or deposits of hydraulic fill. Such soils can act as liquids in transmitting vertical loads as horizontal pressures. Excessive loads may be produced by even a thin layer of soft mud near the bottom of the bulkhead. Engineers should not attempt construction where the bottom includes soft material 5 feet or more deep. They must first remove the soft material and replace it with granular material. Building bulkhead quays is satisfactory if all the materials involved are cohesionless sand or similar soil.

c. Reducing pressures.

(1) The soft mud over the area is dredged and wasted. A sand blanket is put down before driving the piles. Sand improves resistance against outward movement of the piles and reduces earth pressure against the piles. Using sand as the entire fill causes little settlement.

(2) A bulkhead is driven into firm strata and backfilled with soft, unstable mud that causes heavy pressures. Stability of the bulkhead increases if a sand dike is placed behind the bulkhead before the hydraulic fill.

d. Methods of increasing stability.

(1) Driving sheet piles to strata which restrain the lower ends of the piles reduces bending moment. It also allows for scouring and overdredging.

(2) Installing a second wale and set of ties at a lower level improves the stability of bulkheads. This underwater work occurs only when more stability is absolutely necessary.

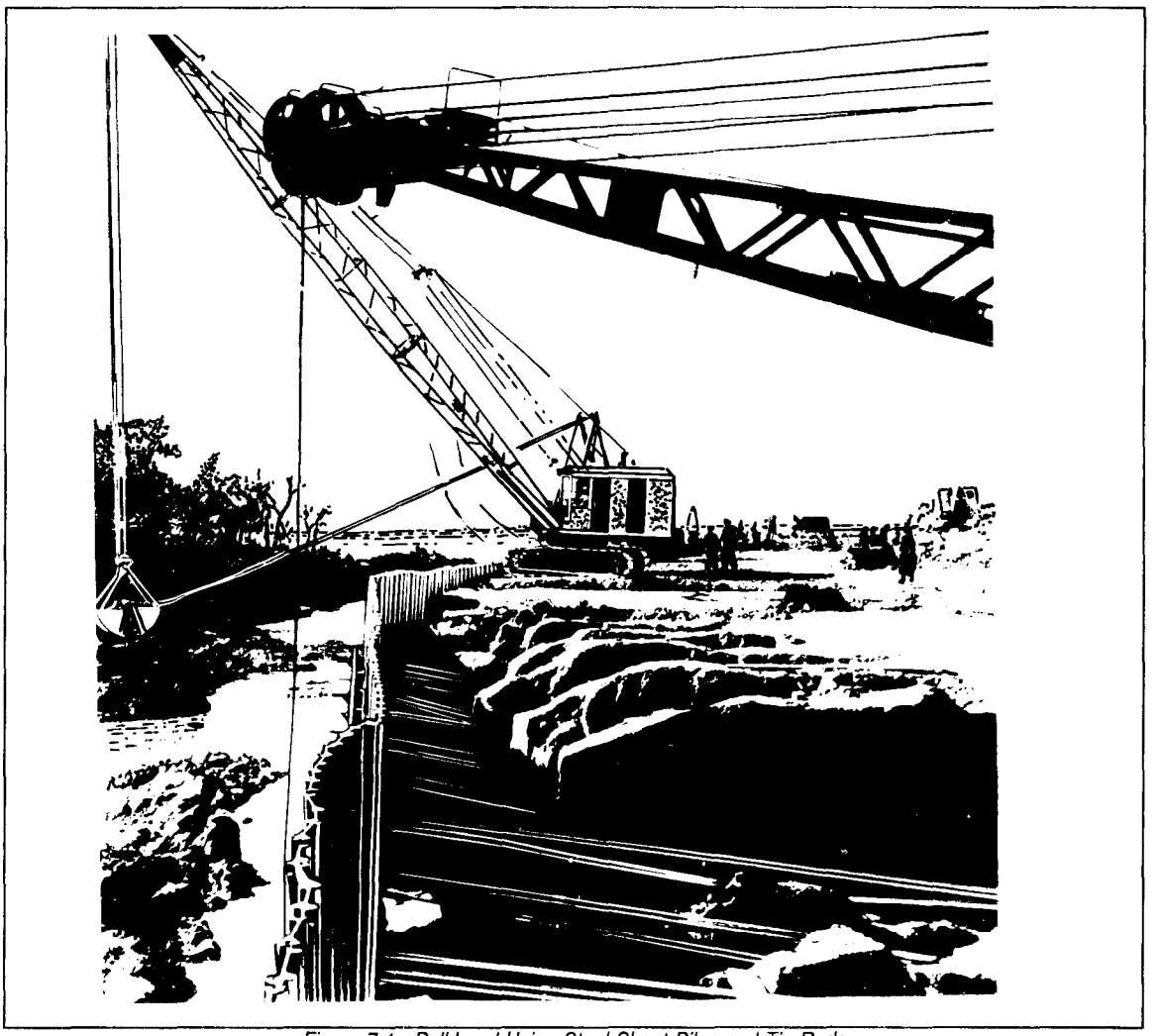

*Figure 7-1. Bulkhead Using Steel Sheet Piles and Tie-Rods*

e. Bulkhead anchorage. Wales can be a pair of channels or I-beams welded to the sheet piles just above mean low water. These are tied to anchors by steel rods tightened with turnbuckles. The anchorage must be a stable formation above the waterline, such as buried deadmen or a pair of steel sheet piles. The point of anchorage may also be below the waterline. Each anchor consists of a pair of bearing-type piles capped by a heavy timber or a reinforced concrete beam. These anchorages must not be closer to the bulkhead than 2 to 3 times the depth from msl to the dredged bottom. Wales and tie-rods are protected with a heavy coating of rust-preventive bituminous material. This coating protects them within a zone about 6 feet inboard of the bulkhead. Back of this zone, heavy corrosion is unlikely except in acid soils or cinders.

f. Importance of the construction sequence.

(1) Dredging of soft material must precede pile driving. But dredging in front of the bulkhead increases the water depth after the fill has been placed and compacted. The lateral load at this time is heavier than at any other time. Material in front of the bulkhead should help stabilize it during backfill. Dredging must occur in several successive cuts to avoid rapid load changes.

(2) Tie-rods are prestressed lightly but uniformly before backfilling. This prevents uneven alignment of the bulkhead under full load. Normally, a turnbuckle is located near the center of each tie-rod. The tie-rod is supported on a pile near the turnbuckle to avoid increased tension as the fill compacts.

(3) Placing fill before backfilling improves the stability of pile anchors.

(4) Except as described under (3), all backfilling is away from the sheet piling, not towards it. For example, fill away from the longitudinal center of the bulkhead and toward its end. This avoids trapping water and soft material against the bulkhead.

**EARTH FILL FOR QUAYS**

a. Fill soils.

(1) Sand, gravel, and other cohesionless materials are most suitable for fill. A slight mix of silt or clay in the cohesionless material is acceptable.

(2) Clay, silt, and mud alone are unsuitable. They may be made usable by mixing sand or gravel with them.

(3) Rock and rubble are good base materials for fill.

b. Dredging operations for fill. Hydraulic dredging is a cheap way to obtain fill. The fill method depends on an analysis of the material obtained in dredging. Use of hydraulic slurry for fill requires--

(1) A retaining bulkhead around the area to receive the fill. Its height depends on the desired finished grade of the filled area and the type of slurry available. Sand compacts very little after the runoff period. However, up to 50 percent reduction in volume may occur with mud.

(2) An area behind the bulkhead large enough to permit material to settle prior to runoff.

(3) Weirs or spillways to control runoff. Runoff from the disposal area carries solids with it. Prepare runoff points to control shoaling.

## BASE AND SURFACE FOR QUAYS

Civil engineering textbooks and FM 5-330 give detailed information for building various quay bases and surfaces. Engineers normally install a curb or string-piece at the face of the quay and concrete foundations for mooring hardware. In anchored bulkheads, these are tied to the anchor. The working surface of the quay is pitched to drain into a ditch at the inshore edge of the working area. This ditch normally continues along each end of the quay to the waterline. The pitch of the working surface is 1 percent of impervious surfacings. However, a flatter pitch to an absolute minimum of 0.25 percent works for concrete paving if there is little rainfall.